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OF THE

INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE.

Vol. II. No. 1.

Saturday, the 26th February, 1916 at 5 P.M., C. V. Raman, Esq., M.A., Vice-President, in the chair.

On the Maintenance of Vibrations by a Periodic Field of Force.

Part I: Experimental.

BY ASHUTOSH DEY.

The effect of a periodic field of force on the motion of a body subject to its influence has already been discussed by Mr. C. V. Raman in Bulletin No. 11.* One of the results of outstanding importance noticed was the series of special relations between the frequency of the field and that of the steady vibration possible under its action. It was shown that the motion is capable of being maintained when its frequency is either equal to, or is $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$ or $\frac{1}{6}$ of the frequency of the field, that is, any submultiple of it, but not when the frequency has any intermediate value. The experimental work and theory published

* And also in the Phil. Mag. January, 1915,—"On Motion in a Periodic Field of Force."

in that paper related to the motion of a system with only one degree of freedom, the period of free vibration of which is determined entirely by the field*. Recently, when experimenting with the electrically maintained vibrations of wires, certain interesting effects have been noticed which may be classed with the phenomena referred to above, but which merit separate discussion, in view of the fact that the system in this case has a series of free periods of its own, quite independently of the field. These will now be described.

Experimental Method and Results.

The present investigation relates to the vibrations of a steel wire about two meters in length, stretched vertically under an adjustable tension, and subject to the transverse periodic force exerted by an electro-magnet placed near some selected point on it. The electro-magnet is excited by an intermittent current from a fork-interruptor of frequency which in this experiment is generally 60 per second. The forced vibrations (having the same frequency as the intermittent current), which are usually excited in the first instance, when the tension of the wire is adjusted for resonance, are of the same form as those described by Klinkert in a paper on electrically maintained vibrations†. It is noticed, however, that when the

* The vibrations studied in that paper were those of the armature of a synchronous motor of the attracted-iron type when not in rotation, under the influence of the magnetic field due to an intermittent current.

† G. Klinkert, Annalen Der Physik, vol. 65 (1898). For a practical application in acoustics of this class of vibrations, see Science Abstracts (1916), page 433.

tension is such that the wire vibrates in two, three or larger number of segments, and the electro-magnet is not too far away from the wire, ***the motion of the usual type first set up is unstable***, and gradually changes form, the nodes ceasing to be points of rest, and the frequency of vibration changes to a value which is a submultiple of the frequency of the fork, For instance, if the wire initially divides up into two segments and vibrates with a frequency of 60, its centre which at first is a node gradually acquires a very considerable motion, and the frequency of the vibration alters to 30. Similarly, if the wire initially vibrates in 3 segments, the frequency changes to 20 when the instability sets in ; when the initial vibration is in four segments, the frequency changes to either 30 or 15, according as the instability does or does not result in a movement of the centre of the wire, and so on.

The rate at which the instability sets in and results in a change of type depends upon the position of the electro-magnet, its distance from the wire, and the strength of the intermittent current which excites it. Generally speaking, the rate of increase of the motion at the nodes is quite small, and it may take some minutes for the change to develop to the fullest extent. The gradual alteration of the form of the vibration may thus be closely studied, and this fact adds considerably to the interest of the experiment from the acoustical point of view. If the distance of the electro-magnet from the wire and strength of the exciting current be suitably proportioned, the vibration with the altered frequency finally reaches a steady

state, the amplitude of vibration then attaining its maximum. If however, the electro-magnet be too near the wire, or if the exciting current be too strong in proportion to the distance, the motion continues to increase in amplitude till the wire finally comes up against the pole of the magnet. This occurs most frequently when the tension is small and the wire divides up initially into a considerable number of segments.

Theory (as will be shown below) indicates that the ordinary forced vibration which is excited when the tension of the wire is adjusted for resonance is not at all essential to enable a vibration having a frequency equal to a submultiple of the frequency of the field to be set up and maintained. This has been tested in the following way :—Two electro-magnets are placed opposite different points on the wire, one or the other of which would be excited at pleasure. The first being placed opposite a point distant about $\frac{1}{8}$th of the length from one end and excited, the tension of the wire is carefully adjusted for resonance so that it vibrates in two, three or larger number of segments as desired. The second electro-magnet is placed exactly opposite a node of this forced oscillation, so that, in accordance with the well-known principle, it is incapable of maintaning a forced vibration of the ordinary kind, when fed with intermittent current. It is observed that when the second electro-magnet alone is excited, the *wire remains practically at rest. But this state of rest is unsatble*, and gradually a vibration develops and attains a large amplitude, its frequency being a submultiple of the frequency of the field,

Investigation by the method of vibration-curves shows that in the motion thus excited, the components having the same frequency as the field or any multiple thereof are practically or entirely absent. To enable the frequency of the field to be compared with that of the motion set up by it, the vibration-curves of some selected point on the wire and of a small style attached to the fork-interruptor are simultaneously recorded on photographic paper.* This may be done either at some stage in the progressive change of vibration-type, or when the motion reaches a final steady state. Sixteen records obtained in the course of the work are reproduced in Plates I and II.

They represent cases in which the frequency of the vibration was either equal to, or $\frac{1}{2}$, or $\frac{1}{3}$, or $\frac{1}{4}$, or $\frac{1}{5}$, or $\frac{1}{6}$ of the frequency of the field. Most of the records were secured at a fairly early stage of the progressive change of the vibration-form. Each record consists of two curves, the upper one represents the vibration of the wire and the lower one represents the time-curve obtained from the fork-interruptor as mentioned. The following table is in explanation of records reproduced in Plates I and II.

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* A method based on the optical composition of the vibrations of the fork and of a selected point on the wire, could no doubt be used for the same purpose as an alternative.

No.	Type.	Point excited.	Point observed.	
1	1st	$\frac{l}{8}$	$\frac{7l}{8}$	
2	2nd	,,	,,	
4	3rd	,,	,,	
5	,,	,,	,,	
10	4th	,,	,,	Group I.
11	5th	,,	,,	
12	,,	,,	,,	
13	,,	,,	,,	
14	6th	,,	,,	
15	6th	at a later stage		
3	2nd	$\frac{l}{2}$	$\frac{7l}{8}$	Group II.
6	3rd	$\frac{l}{3}$	$\frac{7l}{8}$	
8	2nd	$\frac{l}{8}$	$\frac{l}{2}$	
7	3rd	,,	,,	Group III.
9	4th	,,	,,	
16	5th	,,	,,	

Part II : Mathematical Appendix.

By C. V. Raman, M.A.

Theory of the Experiments.

The attractive force of the electro-magnet in the experiments described in Part I, is exercised on a very small region of the wire, which may practically be treated as a mathematical point. The essential feature of the case which enters into the explanation of the phenomena noticed above, is that this attractive force is not a simple function of the time but depends also on the position, at the particular epoch, of the point on the wire with reference to the pole of the electro-magnet. In other words, the expression for the maintaining force is not independent of the form of the maintained motion. For the present purpose, we may write it as a product of two functions, one of which involves only the time, and the other is determined by the position of the wire in the field. Thus

$$\text{Force} = F(y_0) f(t)$$
$$= F(y_0) \sum_{n=0}^{n=\infty} a_n \cos\left(\frac{2\pi rnt}{T} - e_n\right)$$

where T/r is the periodic time of the field and y_0 is the displacement of the wire at the point x_0 (opposite the pole of the electro-magnet) from its position of equilibrium. y_0 being positive when measured towards the pole, $F(y_0)$ increases with y_0 and may be taken to be unity when $y_0 = 0$. We may expand $F(y_0)$ by Taylor's theorem and write it in the form $(1 + by_0 + cy_0^2 + \text{etc.})$. If the force varies inversely as some power of the distance between the

pole and the wire*, it may readily be shown that the constants b, c, &c. are all positive. The complete expression for the force which may be assumed to act at the point x_0 of the wire, is thus

$$(1 + by_0 + cy_0^2 + \text{etc.})\ \Sigma\, a_n \cos\left(\frac{2n\pi rt}{T} - e_n\right)$$

We may now consider first, the *ordinary forced vibration.* This may be obtained by the method of successive approximations. To begin with, we may neglect the quantities by_0, cy_0^2 &c., in the expression for the maintaining force, which then assumes the simple form $\Sigma\, a_n \cos\,(2\pi rnt/T - e_n)$.

Since the forced vibration is of negligible amplitude except when the period of the field is more or less nearly equal to one of the free periods of the wire, the harmonic components in the motion may be determined, term by term, from the corresponding components of the impressed force. The forced vibration may therefore be written as :—

$$\sum_{n=1}^{n=\infty} a_n\, k_n \sin\frac{n\pi x}{\alpha} \sin\frac{n\pi x_0}{\alpha} \cos\left(\frac{2n\pi rt}{T} - e_n - e'_n\right)$$

where α is the length of the string or of each vibrating segment, and k_n, e'_n are quantities, which, in respect of each harmonic, may be expressed in terms of the natural and impressed frequencies of vibration and of the decrement of the free vibrations. If x_0 is equal to α or any multiple of it, the forced vibration becomes negligibly small, the periodic force having an inappreciable effect when applied at a node.

* From the measurements made by Klinkert over a limited range, it would appear that the attractive force on the wire varies inversely as the square root of the distance.

An interesting example in which the formula given above may be applied, is that of a single impulse acting at the point x_0, once in each period of vibration. The coefficient a_n is then the same for all the harmonics and $e_n = 0$ for all values of n. It may readily be shown that if the period of the forced vibration in this case is somewhat greater or somewhat less than the period of free vibration of the string, the form of the maintained vibration is practically the same as that of a string plucked at the point x_0. For, the phase-constants e'_n are then practically all equal to *zero* and π respectively.

Further, k_n is then practically independent of the dissipation of energy (whatever this may be due to) and is inversely proportional to the difference between the squares of the natural and impressed frequencies. For different harmonics, k_n is proportional to $1/n^2$ and the expression for the forced vibration is then of the form

$$\pm \sum_1^\infty \frac{1}{n^2} \sin \frac{n\pi x}{\alpha} \sin \frac{n\pi x_0}{\alpha} \cos \frac{2n\pi rt}{T}$$

and is thus similar to that of a string plucked at x_0 in the same direction as the periodic impulses or in the opposite direction, according as the natural frequency is greater or less than the frequency of the impulses* If the periodic force instead of being impulsive, has a finite constant value during a part fraction 2β of the period and *zero* at other times, the maintained

* It is assumed of course that the free periods of the wire, form a harmonic series. This may be subject to modification if the wire is imperfectly flexible or yields at the ends.

vibration in the two extreme cases assumes the form

$$\pm \sum_{1}^{\infty} \frac{1}{n^3} \sin \frac{n\pi x}{\alpha} \sin \frac{n\pi x_0}{\alpha} \sin \frac{2n\pi r\beta}{T} \cos \frac{2n\pi rt}{T}.$$

If β be small, this is practically of the same type as the expression for a plucked string in respect of the first few harmonics, but would differ from it in respect to the harmonics of higher order.

The next step is to introduce a correction in the expression for the impressed force on account of the neglected terms by_0, cy_0^2 etc. On substitution of the value of y_0 first found in these terms and simplifying the product $F(y_0) f(t)$, it is seen that the correction results only in alterations of the amplitudes and phases of the harmonic components of the impressed force, but no new terms are introduced of which the frequency is not the same as that of the field or a multiple thereof. This shows that the corrections cannot by themselves, result in an alteration of the frequency of the forced vibration, so long as we assume, in the first instance, that y_0 has the same frequency as the field of force. They may however result in the impressed force (and therefore also the maintained motion) including such partial components as are absent in the field itself.

A consequence of the preceeding formulæ which is of particular importance is that, when the impressed force is of an impulsive character, the corrections by_0, cy_0^2 &c. when introduced, cannot result in any alterations in the *relative* amplitudes and phases of the components of the maintained vibration. For, the product $F(y_0) f(t)$ is *zero* at all times except at the particular instant in each period at which the

impulse acts, and as these epochs are fixed, any change in F (y_0) can only result in the amplitudes of *all* the components of the impressed force, being increased or decreased in the same proportion, their phases remaining unaltered. The non-uniformity of the field may thus affect the amplitude of the vibration but cannot alter its form, it being assumed, of course, that the amplitudes are not so large as to alter the free periods. This peculiarity of the action of a non-uniform impulsive field is the explanation of certain interesting observations described but not explained by Klinkert in the paper referred to above. Klinkert experimented with two wires, both electro-magnetically maintained, one of which was self-acting and the other was worked by a current on a separate circuit, rendered intermittent by the vibration of the first wire. The vibration-curves of the two wires showed a marked dissimilarity, a special feature of interest being the fact that the vibration of the second wire, when at its maximum, was practically similar to that of a plucked string. In view of what has been said above, this result will be readily understood. The magnetic field is of appreciable strength, only during a small fraction of the period and may thus be regarded as of an impulsive character. When there is an appreciable difference between the natural and impressed frequencies of vibration, the form of the motion approximates to that of a plucked string, and this is what is actually observed when the exciting current is rendered intermittent by an independent interruptor. It is when the natural frequency is somewhat greater than the

impressed frequency, that the vibrations of the largest amplitude and those that show the closest similarity to the vibrations of a plucked string are obtained. For the vibrations are then nearly in the same phase as the impulses, and as an increase in the amplitude brings the position of the wire at which the impulses act, closer to the electro-magnet and therefore still further increases the magnitude of the impulses, a vibration of large amplitude may be maintained in spite of the difference between the natural and impressed frequencies of vibration. The increase of natural frequency due to a large amplitude would also tend to encourage the assumption of this form of vibration and to make it stable. The conditions are, however, entirely different when the vibrating wire is a self-acting interruptor which determines the period and character of its own excitation, and a detailed mathematical theory of the vibration-forms obtained with it, must be reserved for separate consideration.

We may now pass on to consider the cases in which the frequency of the vibration is not the same as the frequency of the field, but is a submultiple of it. To fix our ideas, we may assume the free vibration of the wire, when it divides up into r segments to have nearly the same period as the field, that is T/r. The period of vibration of the wire as a whole, is therefore T. Experiment shows that the forced vibration having the period T/r may be unstable, giving place to a vibration in the period T. To explain this result, we may examine the effect, according to our equations, of superposing a small vibration of period T upon

the ordinary forced vibration, if any, of period T/r. If by_0, cy_0^2 etc. be neglected, there is no component in the impressed force having the period T, and the initial disturbance assumed would die away in the ordinary course. It is not possible therefore to obtain the phenomena illustrated in Plates I and II with uniform fields of force. With non-uniform fields, the additional terms by_0, cy_0^2 etc. have to be taken into account, and it may readily be shown on expanding the product $F(y_0)f(t)$ in a series of sines, that there would be a term of period T in the expression which would, under certain circumstances, be capable of magnifying the assumed disturbance continually, till it assumes a large amplitude. For example we may take $r=2$, and the initial disturbance to be, say, $\gamma \sin \frac{2\pi t}{T}$. The product $by_0 a_1 \cos\left(\frac{4\pi t}{T} - e_1\right)$ would contain a term $ba_1 \gamma \sin \frac{2\pi t}{T} \cos\left(\frac{4\pi t}{T} - e_1\right)$ which on being expanded is seen to include a component $ba_1 \gamma \sin e_1 \cos \frac{2\pi t}{T}$. This is proportional to the assumed disturbance, has the same period, and has a phase in advance of it by 90°. It would therefore tend to magnify the assumed disturbance of period T, till the latter reaches a considerable amplitude. An explanation of the phenomena is thus possible for the case $r=2$, in which no part is played by the component of y_0 having the same frequency as the field. For the cases in which $r=3$ or 4 &c., we have to proceed to a higher degree of approximation by taking into account not only the assumed disturbance of frequency $1/T$, but also other subsidiary compo-

nents whose frequencies are multiples of $1/T$ and play a part in the magnification or maintenance of the vibration of that frequency. If in the distribution of the field $F(y_0)$, only the first correction term by_0 is taken account of, the analysis proceeds practically on the same lines as that contained in Bulletin No. 11, except that, instead of the equations of motion for one degree of freedom, the general formula for the normal co-ordinates in the forced vibrations of the wire would have to be used. The same general result would be obtained, that the components in the motion having the same frequencies as the field or any multiple of it would not play any part in the maintenance of the motion of the kind now considered. We have already seen how this indication of theory may be verified experimentally. When however the correction terms of higher order, that is cy_0^2 &c., are considered, some modification of this general statement, might become necessary.

Summary and Conclusion.

The paper considers experimentally and theoretically a case of vibrations maintained by a *non-uniform* periodic field of force which is of some practical importance. It is shown that when a wire divides up into two or more segments and vibrates under the transverse attraction of an electro-magnet, the motion which has the same frequency as the field, may be rendered unstable by the non-uniformity of the field and then passes over into one, the frequency of which is a submultiple of the frequency of the field. Photographic records illustrating the first six cases of the kind are presented with the paper. It is also shown

that a motion of this type may be set up and maintained even where the attracted point on the wire is a node and the ordinary forced vibration is therefore absent. The effects of the non-uniformity and of the periodic variation of the field on the ordinary forced vibration, are also considered in detail and the mathematical theory of certain effects noticed by Klinkert is set out.

On the Application of the Physical Property $\frac{\text{Atomic volume}}{\text{Density}}$ of the elements in determining the Degree of Chemical Affinity in simple chemical combinations.

By Manindra Nath Banerjee.

(Preliminary Note).

Various physical properties of the chemical elements, such as *atomic volume*, melting points, extensibility, thermal expansion, conductivity for heat and electricity, heat of formation of oxides and chlorides, magnetic and diamagnetic properties, refraction equivalents, (*vide*—on these properties, Lothar Meyer, *Modern Theories of Chemistry*, 1883, p. 144 ff), "Hardness of the free elements" (Rydberg, *Zeitscr phys.* 33,353, 1900) "change of volume on Fusion" (M. *chem.* Topler, *Wied. Ann.* 53,343,1894), "viscosity of salts in aqueous solution (Jul. Wagner. *Zeitscr. phys. chem.* 5,49,1890), "Colour of Ions" (Carey Lea, Sill. *Am. Journ* [3], 49,343,1894), "Ionic Mobility" (Bredig, *Zeitshr. Phys. Chem.* 13,289,1894), "Compressibility of solid elements" (T. W. Richards,

Zeitschr. phys. chem. 61, 183, 1908) *etc.*, have been shewn to be more or less marked periodic character in reference to atomic weight and to add to this we may shew that the $\frac{\text{Atomic volume}}{\text{Density.}}$ of the elements is also a periodic function of atomic weights. We have already shewn in a preliminary note "On the Relationship of Atomic Volumes and the specific gravities of the elements" (*vide* Proc. of the Indian Association for the cultivation of Science, September, 1915) that $\frac{\text{Atomic volume}}{\text{Density}}$ number has a marked relationship with the *chemical activity* or the *chemical affinity* of the elements. Hence the periodicity of *chemical affinity* with reference to atomic weights is quite apparent. This attaches much importance to the $\frac{\text{Atomic volume}}{\text{Density.}}$ number of the elements, the proper investigation of which we are now engaged in. One of the results of such an investigation is the application of it in determining the degree of chemical affinity in simple chemical combinations. In doing this, we have to use two formulæ which, for the present, may be taken as empirical ones. These are—

$$(1) \quad \frac{x \dfrac{A}{D^2} \; y \dfrac{A'}{D_1^{\,2}}}{xy \text{ (mol. wt. of the comp).}} \qquad (2) \quad \frac{xy \left(x \dfrac{A}{D^2} \; y \dfrac{A'}{D_1^{\,2}} \right)}{\text{mol. wt. of the comp.}},$$

where A/D^2 and $\frac{A'}{D_1^{\,2}}$ are the $\frac{\text{Atomic volume}}{\text{Density.}}$ of the component elements and x and y their number of atoms respectively. Of these the former is meant for combination between two component elements of opposite character as electropositive and electronegative ones while the latter is meant for combinations between elements of the same character,

i.e. between two electronegative or two electro-positive ones. The numerical values of these are considered as tangents of some angles which may be found in a Logarithmic table. These angles are all plotted in a quadrant, those obtained from the first formula *positively* (*against* the direction of the hands of a watch), while those obtained from the second formula *negatively* (*with* the direction of the hands of a watch). Thus the latter angles have their complimentary angles. These complimentary angles, together with the former set of angles are arranged in a table in their decreasing order and their corresponding numerical values against them as also putting the solid, liquid and gaseous compounds separately. Thus we have a complete table which illustrates very clearly the degree and character of chemical affinity exerted in the combinations (for the tables *vide* our paper on "ATOMIC IMPACT"—Annual Report, Indian Association for the Cultivation of Science, 1913). The subject is still under investigation and when it is complete a detailed description of these may be conveniently published.

On the Alteration of Pyrite occurring in Steatite.

By SURES CHANDRA DATTA, M.Sc.

Introduction.

With the kind permission of Mr. Coggin Brown, Assistant Superintendent of the Geological Survey of India and sometimes Professor of Geology at the Presidency College, Calcutta, I had an opportunity of accompanying a party of Presidency College students to the Pindari Glacier (lat. 30°-15½′; long. 80°-2′) in charge of Professor Das Gupta and the specimens that are described in this short note were obtained during this trip in the month of June and July, 1913.

Collection of Specimens.

On the day the party was proceeding beyond Bageswar, 26 miles North of Almorah, I came across a specimen of steatite with pseudomorphs of limonite after pyrite, embedded in it. These pseudomorphs, it must be mentioned, almost always contain kernels of unaltered pyrite within. The next day on the way to Loharkhet, 49 miles north of Almorah, another specimen of steatite with several limonite pseudomorphs, was collected by me and on careful examination it was observed that the occurrence of pseudomorphs of limonite after pyrite in steatite was very common in this latter area.

Description of Steatite.

The rocks between Bageswar and Loharkhet are quartzite, steatite and limestone. There is a considerable number of landslips in this part, especially on the way to Loharkhet, exposing sometimes the shin-

ing steatite schists on the mountain sides. In some specimens of quartzite near Bageswar, flakes of talc occur. The limestone is magnesian. Steatite is more or less white, shining with characteristic soapy feel and is very impure—the impurity, chiefly carbonate, sometimes attaining a considerable proportion and even in some cases the amount of carbonate—dolomite—found mixed up with it, has been estimated to be about 65 per cent. Ferruginous impurity is comparatively speaking very insignificant and in some specimens, it has been found to be about 1·5 per cent. (estimated as Fe_2O_3). In some parts of steatite there are individuals, and in other parts aggregates, of limonite pseudomorphs. From these pseudomorphs originate cracks more or less in parallel directions *i.e.*, parallel to the foliation of the schists. The cracks are filled up with talc and quartz and there is no limonite in them. It is well known that the change of pyrite to limonite is accompanied with an increase in volume (1), and it is not unlikely that these cracks were formed, during the process of this alteration, the cracks being younger than the original pyrite crystals. The talc flakes filling up the cracks are also evidently younger than the cracks and were very likely formed from solution of dolomite and quartz. The talc flakes filling up these cracks have no regularity in their arrangement while the talc flakes occurring in steatite itself but not in the cracks appear to have a parallel banded course and running also roughly parallel to the direction of the cracks just mentioned.

(1) Monographs of the United States Geological Survey. Vol. XLVII, p. 215.

Besides the dolomite and talc flakes mentioned above, patches of quartz have also been observed in the rock. The dolomite and quartz have both signs of pressure. The films of talc mentioned above intervene between these two and here, as a matter of fact, the proportion of quartz and dolomite is such that talc can be formed with the subsequent introduction of moisture, for it is well known that talc is in general a mineral of the zone of weathering (1). In the case of talc occurring in the cracks, dolomite and quartz were transported in solution; while the formation of talc occurring in the rock was due to dolomite and quartz originally present in the rock and a subsequent introduction of moisture. Sometimes chlorite with a slight green pleochroism and straight extinction has been found to be associated with this steatite rock. This chlorite decomposes at the ends into grains of dolomite and limonite, with seggregations of quartz which have inclusions of very fine fibres of chlorite in the same state of decomposition and in the same way. Decomposition always begins from the ends and not from the sides. Possibly this chlorite is an intermediate stage between the dolomite of the schist and iron ores on the one hand and the original rock from which these minerals have gradually and subsequently been developed, on the other. This characteristic decomposition of chlorite into dolomite, quartz and limonite is an indication, says Rosenbusch, of the zone of weathering (2).

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(1) Monographs of the United States Geological Survey, Vol. XLVII, p. 350-351.

(2) Ibid, p. 347.

Description of Limonite.

Limonites occurring in steatite have been examined. As mentioned before they are always pseudomorphs after pyrite and these pseudomorphs are sometimes single individuals and sometimes aggregates—the aggregates being sometimes elongated in the direction parallel to the foliation of steatitic schists. Rock is more or less loose round these pseudomorphs within short distances and these less compact portions of the rock are coloured brown, the colour fading with the distance from the central pyrite. Forms present in the pseudomorphs are cubes and combinations of cubes and pyritohedra but pyritohedra are not present alone. Whenever pyritohedra occur they occur always in small size with a tendency to pass into striations—these striations being parallel to the edges of cube and pyritohedron. It has already been said that almost all the pseudomorphs have remnants of pyrite in them. There is no carbonate of iron in limonite and no dolomite included in pyrite. There are grains of quartz in pyrite and in limonite. Possibly these quartz grains are the same as the quartz of the quartzite in steatite but they got included in pyrites when these pyrite crystals were formed. The pseudomorphs do not contain gold or copper. Limonite has not been formed by infiltration as there is no break between pyrite and limonite. This suggests that the deposition of limonite has taken place simultaneously with the solution of pyrite. In limonite there are portions quite light and portions which are quite dark coloured. The dark coloured portions are more or less circular in section and are gradually merging into

portions quite light, there being no sharp line of demarcation between these two. This structure had possibly been developed by the nature in which pyrite crystals have been attacked, to be mentioned below, by the circulating solution and by the pressure consequent on the increase of volume when limonite has been formed from pyrite. Limonite does not develop in the zone of anamorphism (1). Moisture and Oxygen are necessary for its formation from pyrite (2). Limonite is formed in the belt of weathering (3). Crystals of pyrite of higher symmetry form where pressure is great (4). Cubes with striations and combinations of cubes and pyritohedra almost reduced to striations are cases of higher symmetry. However, formation of limonite indicates the stage of the zone of weathering, whereas the formation of pyrite denotes the stage of deep-seated zone. The nature of the occurrence of pyrite crystals and the formation of their aggregates suggest the possibility that ferruginous matter formerly present in the original rock which is linked with chlorite, as mentioned before, was transported by some circulating solution and concentrated at number of centres in the rock itself—these centres being chemically active and the whole process taking place in the deep-seated region *i.e.* in the zone of anamorphism These pyrites, when brought up within the zone of weathering, began to

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(1) Monographs of United States Geological Survey, Vol. XLVII, p. 233.

(2) Ibid, p. 216.

(3) Ibid, p. 216.

(4) Ibid, p. 215.

change into limonite by the bicarbonate solution derived from the solution of enormous quantities of carbonate in the form of dolomite in steatite. This alteration is well known (1). It has also been proved experimentally (2). During this change sulphuric acid is produced which has loosened the steatite round altered pyrite crystals.

Planes of Chemical Alteration in Pyrite.

The way in which the bicarbonate solution attacks pyrite has been found to be interesting. As far as I am aware there has been no mention of this phenomenon in the current literature. Rosenbusch (3) says that when pyrite changes to limonite the alteration begins from periphery towards the interior. The solution no doubt acts from the periphery but alteration progresses inwards through planes parallel to (100) and (111)—the former plane being altered with greater energy and more easily as evidenced from the fact that in the region of contact between limonite and pyrite and in the boundary of the latter, minute alteration products of limonite parallel to (100) and (111) do occur—those parallel to (100) being more numerous and also greater in length. The alteration products sometimes occur in zig zag lines which when observed under the microscope very carefully appear to be but parallel to the traces of (100) and (111) *i.e.*, can be split up into traces of (100) and (111)—the former being greater in number and in length. In a

(1) A text Book of Mineralogy by E.S. Dana, p. 301.

(2) Econ. Geol. ii, pp. 14-23, 1907.

(3) Rosenbusch mikr Physio Bd. I, pt. 2, p. 9, 1905.

slide of pyrite there occur two parallel rods of limonite, parallel to striation, parallel to the edges of cube and pyritohedron. These parallel thick bands of limonite are crossed by a similar band at right angles to both; while there are also very fine alteration products parallel to minute traces of (111) in these rods and at their junctions or corners at the crossing. There are indistinct cleavages in pyrite, parallel to (100) and (111) (1). Thus it is seen in this case of pyrite, the physical property of cleavage and the chemical property of alteration are in the same plane.

Summary.

It has been the main purpose of this note to establish :—

(1) That alteration of pyrite to limonite within steatite schists is attended with increase in volume giving rise to cracks round pyrite crystals and this is partially responsible for the production of a peculiar structure within limonite.

(2) That the materials necessary for the production of talc were accumulated in two different ways, *viz.*, by transportation and in situ—transportation being very local in character in as much as it was effected from one part of the rock to another near about.

(3) That chlorite fibres decompose at the ends and not at the sides and that this chlorite, as mentioned before, is linked with the

(1) Rock minerals by Iddings, p. 523, 1906.

original rock which, at its some period of geological history, gave rise to pyrite crystals of higher symmetry than that of pyritohedron, in deep-seated zone, from the ferruginous matter present in the rock itself in some form or other.

(4) That pyrite crystals alter to limonites being attacked in planes parallel to (100) and (111)—the former plane being more easily and energetically attacked.

In conclusion I wish to thank Mr. H. C. Das Gupta, M.A, F.G.S. for the facilities given to me to work in the Geological Laboratory, Presidency College and also for helping me with some suggestions while preparing this note and I also wish to thank my old teacher Mr. Vredenburg, A.R.S.M., A.R.C.S. of the Geological Survey of India for having kindly gone through the manuscript.

Ripon College, Calcutta,
February, 1916.

PROCEEDINGS

OF THE

INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE.

Vol. II. No. 2.

Saturday, the 29th, July, 1916 at 5 P.M. The Hon'ble Justice Sir Asutosh Mukerjee, KT., Saraswati, Shastra-Vachaspati, C.S.I., M.A., D.L., D.SC., F.R.S.E., F.R.A.S., &c., Vice-President, in the chair.

On the Wolf-notes of the Violin and Cello: How are they caused?

By C. V. Raman, M.A.

It has long been known that on all musical instruments belonging to the violin family there is a particular note which it is difficult to elicit in a satisfactory manner by bowing. This is called the "wolf-note," and when it is sounded the body of the instrument is set in an unusual degree; and it appears to have been realized that the difficulty of maintaining the note steadily is due in some way to the sympathetic resonance of the instrument.* In a recent paper,† G. W. White has published some interesting experimental work on the subject, confirming this view. The most striking effect noticed is the *cyclical* variation in

* Guillemin,—"The Application of Physical Forces," 1877.

† G. W. White,—Proc. Camb. Phil. Soc., June, 1915.

the intensity of the note when the instrument is force to speak at this point. White suggests as an explanation of these fluctuations of intensity that they are due to beats which accompany the forced vibration impressed on the resonator when the impressed pitch approaches the natural pitch of the system. The correctness of this suggestion seems open to serious criticism. For, the beats which are produced when a periodic force acts on a resonator are of brief duration, being merely due to the superposition of its forced and free oscillations, and when, as in the present case, the resonator freely communicates its energy to the atmosphere and the force itself is applied in a progressive manner and not suddenly, such beats should be wholly negligible in importance, and should, moreover, vanish entirely when the impressed pitch coincides with the natural pitch. In the present case the feature is the *persistency* of the fluctuations of intensity and their markedness over a not inconsiderable range; and it is evident that an explanation of the effect has to be sought for on lines different from those indicated by White. I had occasion to examine this point when preparing my monograph on the "Mechanical Theory of the Vibrations of Bowed Strings," which will shortly be published, and the conclusions I arrived at have since been confirmed by me experimentally.

From the mechanical theory, it appears that when the pressure with which the bow is applied is less than a certain critical value, proportionate to the rate of dissipation of energy from the vibrating string, the bow is incapable of maintaining the ordinary mode of vibration in which the fundamental is dominant, and

the mode of vibration should progressively alter into one in which the octave is the predominant harmonic‡. In the particular case in which the frequency of free oscillation of the string coincides very nearly with that of the bridge of the violin and associated masses, the mode of vibration of the string is *initially* of the well-known type in which the fnndamental is dominant. But the vibrations of the string excite those of the instrument, and the vibrations of the latter increase in amplitude, the rate of dissipation of energy increases continually till it outstrips the critical limit, beyond which the bow fails to maintain the usual type of vibration. As a result of this, the mode of vibration of the string progressively alters to a type in which the fundamental is subordinaie to the octave in importance. The vibration of the belly then begins to decrease in amplitude, but, as may be expected, this follows the change in the vibrational form of the string by a considerable interval. The decrease in the amplitude of the vibrations of the belly results in a falling off of the rate of dissipation of energy, and, when this is again below the critical limit, the string regains its original form of vibration, passing successively through similar stages, but in the reverse order. This is then followed by an increase in the vibrations of the belly, and the cycle repeats itself indefinitely. The period of each cycle is approximately twice the time in which the vibrations of the belly would decrease from the minimum, if the bow were suddenly removed.

‡ Compare with the observations of Helmholtz,—'Sensations of Tone,' English Translation by Ellis, p. 85.

The foregoing indications of theory are amply confirmed by the photographs of the simultaneous vibration-curves of the belly and string of a cello at the wolf-note pitch. It is seen that the form of vibration of the string alters cyclically in the manner predicted by the theory, and that the corresponding changes in the vibration-curve of the belly *follow* those of the string by an interval of about quarter of a cycle. That the two sets of changes are dynamically interconnected in the manner described is further confirmed by the prominence of the octave in both curves at the epochs of minimum amplitude. The explanation of the cyclical changes given above is also in accordance with the observed fact that they disappear and are replaced by a steady vibration when the ratio of the pressure to the velocity of bowing is either sufficiently increased or sufficiently reduced. In the former case the string vibrates in its normal mode, and in the latter case the fundamental disappears altogether and the string divides up into two segments.

Effect of Muting on the "Wolf-note."

Since the pitch of the wolf-note coincides with that of a point of maximum resonance of the belly, we should expect to find that by loading the bridge or other mobile part of the body of the instrument important effects are produced. This is readily shown by putting a mute on the bridge. The pitch of the wolf-note then falls immediately by a considerable interval. On the particular 'cello' I use, a load of 17 grammes fixed at the highest point of the bridge lowers the wolf-note pitch from 176 to 160 vibrations per second. A larger load of 40·4 grammes depresses

it further to 137 vibrations per second, and also causes two new but comparatively feeble resonance-points to appear at 100 and 184 respectively, without any attendant cyclical phenomena. An ordinary brass mute has a very similar effect.

The Formation of Violin-tone and its Alteration by a Mute.

The positions of the frequencies of maximum resonance of the bridge and associated parts of the belly for the notes over the whole range of the scale are undoubtedly of the highest importance in determining the character of violin-tone, and the explanation of the effect of a mute on the tone of the instrument is chiefly to be sought for in the effect of the loads applied on the frequencies of the principal free modes of vibration of the bridge and associated parts of the belly. The observations of P. H. Edwards on the effect of the mute* are evidently capable of explanation on the basis of the lowering of the frequencies of maximum resonance by the loading of the bridge. But a more detailed understanding of the dynamics of the problem requires further theoretical and experimental investigation. Recently, I have secured an extensive series of photographs showing the effect on the motion of the bridge in its own plane produced by fixing a load on it at one or other of a variety of positions. The close parallelism between the effect of loading, as shown by these photographic curves and

* P. H. Edwards, Physical Review, January, 1911.

† Giltay and De Hass, Proc, Roy. Soc. Amsterdam, January 1910. See also E. H. Barton and T. F. Ebblewhite, Phil. Mag., September 1910, and C. V. Raman, Phil. Mag., May 1911.

as observed by the ear, seems to show that the motion of the bridge in its own plane determines the quality of violin-tone to a far greater extent than might be supposed from the work of Giltay and De Haas†. A detailed discussion of this and other problems relating to the physics of bowed instruments is reserved for a separate communication.

Several other interesting effects have since been noticed, of which the following is a summary :—

(a) Cyclical forms of vibration of the G-string and belly of a 'cello may also be obtained when the vibrating length is double that required for production of the wolf-note, that is, when the frequency is half that of the wolf-note. In this case, when the pressure of the bow is sufficient to maintain a steady vibration, the second harmonic in the motion of the belly is strongly re-inforced. When the pressure is less than that required for a steady vibration, cyclical changes occur, the principal fluctuations in the motion, both of the string and the belly, being in the amplitude of the second harmonic. In this, as in all other cases, the cyclical changes disappear and give place to a steady vibration, when the bow is applied at a point sufficiently removed from the end of the string. In this particular case, a large, *almost soundless* vibration may be obtained by applying the bow rather lightly and rapidly at a point distant one-fifth or more of the length from the end; the octave is then very weak in the vibration of the string, but may be restored, along with the tone of the instrument, by increasing the pressure of the bow.

(b) The 'cello has another marked point of resonance at 360 vibrations per second. The pitch of this is also lowered by loading the bridge.

(c) When the vibrating length of the G-string or D-string of the 'cello is about a fourth of the maximum or less, cyclical forms of vibration may be obtained at almost any pitch desired, by applying the bow with a moderate pressure rather close in the bridge.

(d) As the frequency of vibration is gradually increased from a value below to one above the wolf-note frequency, the phase of the principal component in the "small" motion at the end of the string, that is also of the transverse horizontal motion of the bridge, undergoes a change of approximately 180°. This is in accordance with theory.

Reversion of Fertile Regions into Sterility in Phanerogamic Plants.

By Surendra Chandra Banarjee, M.A, B.Sc.

The species "Crotolaria sericea, Retz." of the sub-order Papilionaceae under Leguminosae, normally flowers in the cold season, generally between November and February. After flowering and fruiting, the plant generally dies away; thus it is an annual herb, although some individuals attain a tall and robust body.

In this plant the sexual reproductive region, or the bract-leaf-region is very well marked and quite distinct from the vegetative, or foliage-leaf-region (Fig. 1). Generally, plants are busy in their early life in building up their body, i. e., adding to and strengthening their frame work. After the vegetative processes are completed, i.e., after the body of the individual has attained the normal dimensions, the development of the sexual organs begins, and is generally localised, i.e. these organs are developed in some definite part of the plant body. This part of the plant body together with the organs of reproduction is known as the bract-leaf-region, or the Inflorescence. The inflorescence is thus the upper or concluding part of the plant body, and the organs of reproduction, namely the flowers, are the ultimate ends of the various branches of the aerial part of the plant body.

There are facts to prove that flowers are modified shoots. The phenomenon observed in the present case is a proof that inflorescence is a modified form of the branch-system in the foliage-leaf-region. Some of

the branches of the inflorescence became sterile and produced foliage leaves towards their tips, while bearing the usual bracts lower down, and others produced a few flowers. Thus sterile or foliage leaves were borne on branches similar to those which normally bear bract-leaves in the axils of which fertile shoots i.e. flowers are produced. So that, the fertile region reverted to sterility, i. e. inflorescence reconverted itself into vegetative region.

The phenomenon was observed on the 24th May 1916, in a seedling which grew up by the side of its old parent which had flowered in the last winter. The seedling brought forth its inflorescence branches while itself had attained a height much shorter than what is normally attained by others in the flowering time in winter.

Normally, the seedlings of this species grow after the rains when their subterranean part, i.e. their root system is busy in collecting food materials, from the moist soil for building up the vegetative body. The seedling under observation rose from a seed in May when the superficial soil was very dry and consequently the root system could not procure the requisite quantity of food materials. Although there was a very scanty supply of food from the soil, the aerial environments of the seedling favoured growth; for the seedling grew up by the side of a tank and in a bush of pine apple and other plants (Fig. 3). Thus it had around it an atmosphere of water vapour from the tank, rendered very hot by the abnormal solar heat of May, 1916. Thus, hot-house conditions prevailed round about the seedling. On account of this insufficient

food supply and forced growth, the plant very soon finished up its vegetative functions in order to take up the reproductive functions and consequently attained a very short stature—the universal sequence of events in a plant life being reproduction following vegetation. But in this case the reproductive activity did not produce satisfactory results, as only a few flowers, and only, perhaps, one or two pods were produced (Fig. 2). So, in order to economise the scanty supply of food at its disposal, the plant again converted its fertile region into vegetative region, apparently with the object of propagating itself by vegetative means; for, much less energy is spent on the production of foliage leaves than on fertile ones. Hence, the season must have had an influence on the reversion.

The seedling in question lived till it flowered in the succeeding winter (end of November, 1916) and thus it behaved like a perennial.

A similar reversion of fertile regions into sterility was observed in the case of a mango inflorescence. A mango tree which is on the bank of a tank bore its inflorescence twigs in the last winter season—when mango trees are normally in flower. The inflorescence twigs, however, curiously changed into vegetative shoots—foliage leaves, with their charactertistic colour and texture, came out from the twig where flowers were expected. Unfortunately no photo was taken at that stage. The probable explanation in that case might have been injury caused by ants, as that individual was full of ants at the flowering time.

A similar reversion is also illustrated by a "Zalacca edulis *Reinw*," a formidable Burmese palm with no

stem and with leaves 16-20 feet long, the petioles of which are armed with very sharp thorns. The inflorescence of this comes out from its base near the ground curving forwards and downwards. One of the branches of the inflorescence has been recorded to have directly ended in a new plant with roots (vide plate 222-223, Plantae Asiaticae Rariores Vol. III. by Nathaniel Wallich, M. & Ph. D. and published in 1830.) (Fig. 4, reduced from the plate quoted above and which can be seen in the Herbarium, Royal Botanic Garden, Sibpore.)

On the Zonal Distribution of PLACENTICERAS TAMULICUM, Kossmat.

BY HEM CHANDRA DAS-GUPTA, M.A., F.G.S.

In the year 1912 I had an opportunity of visiting a part of the well-known cretaceous rocks of Southern India in charge of a party of students from the Presidency College, Calcutta. The geology of the area has been very fully described by the late Dr. Blanford(1), while the fossils, in the first place, were thoroughly described by Dr. Stoliczka(2). Ever since a fairly large volume of literature has appeared dealing with the geological features of the area.

The *ammonites* found in the beds include the genus *Placenticeras* represented by 3 species viz :—*Pl. tamulicum* Kossmat, *Pl. syratale* Morton and *Pl. warthi* Kossmat. A fourth species, collected by Mr. P. N. Bose from the Bagh beds of India, has been

(1) Mem. Geol. Surv. Ind., Vol. IV, pp. 1-217.
(2) Pal. Ind. Ser. I, III, V, VI, VIII, Vols. I-IV.

described and named *P. Mintoi* by Mr. Vredenburg.[3] This genus has also been recorded from many places outside India.

An account of the zonal distribution of the species belonging to this genus was published by Böhm [4] in 1898 and by Mr. Vredenburg in 1908[5]. Two additional species have been fully described by Sommermier from the lower cretaceous rocks of Northern Peru[6]. Accordingly, as known at present, the zonal distribution of the species of *Placenticeras* is substantially the same as that published by Mr. Vredenburg and to his list the two species of Sommermier, just referred to, have only to be added.

My observations in the Southern Indian creteceous rocks have shown, however, that a slight change in this table is necessary and the reasons for such an alteration are recorded in this short note.

Shillagoody is a small village situated within the Ariyalur area[7]. The place is known to be fossiliferous and the following fossils have hitherto been recorded from these beds :—

1. *Pentacrinus* sp.
2. *Axinæa sub-planata* Stol.
3. *Anomalocardia (Scapharca) ponticerina* d'Orb.
4. *Vola quinquecostata* Sow.
5. *Plicatula striato-costata* Stol.

(3) Rec. Geol. Surv. Ind., Vol. 36, pp. 109-121.

(4) Zeitschr. d. deutsch. geol. Gesselsch., Vol L. (1898), p. 200.

(5) Op. cit., p. 120.

(6) N. J. f. Min. Geol. u. Pal. Beilage-Band., xxx (1910), pp 330-336.

(7) Mem. Geol. Surv. Ind., Vol. iv., p. 131.

6. *Plicatula instabilis* Stol.
7. *Cerithium (Sandbergeria) Trichinopolitense* Forb.
8. *Chemnitzia sp. indet.*
9. *Trochactæon truncatus* Stol.
10. *Nautilus sublævigatus* d'Orb.

Some of the fossils mentioned in the foregoing list were obtained by the Presidency College party but the find includes also the following :—

1. *Hemiaster tuberosus* Stol.
2. *Hemiaster cristatus* Stol.
3. *Terebratula subrotunda* Sow.
4. *Veniella obtruncata* Stol.
5. *Leptomaria indica* Forbes.
6. *Protocardium hillanum* Sow.
7. *Trigonia Brahminica* Forbes.
8. *Ostrea cf. acutirostris* Nilss.

Besides, one specimen of *Placenticeras* has been collected in the Shillagoody beds in association with the fossils just mentioned and a comparison with the known species of the genus at once proves its identity with *Placenticeras tamulicum* Kossmat (8).

As far as we know at present *Placenticeras tamulium* Kossmat is confined to the upper part of the Trichinopoly (=lower senonian) beds and, as a matter of fact, a special stress has been laid upon the occurrence of this fossil in assigning the Trichinopoli beds

(8) Kossmat—Untersuchungen über die Südindische Kreidformatian, pp. 78-80. Pl. VIII, fig. 1.

to the lower senonian stage [9]. Accordingly the presence of this fossil at Shillagoody shows that either (i) at Shillagoody there exists a small Trichinopoly inlier; or (ii) *Placenticeras tamulicum* Kossmat has a wider vertical range than what is known at present.

A study of the fossils found in association with *Placenticeras tamulicum*, shows that nearly all of them have been recorded from the Ariyalur (=campanian) beds. According to Stoliczka *Protocardium hillanum* has been recorded only from the Trichinopoly group. This species is, however, of very wide geological limit and in Europe the species has been found almost everywhere 'in cenomanian, turonian and senonian deposits '[10]. Accordingly the occurrence of *Protocardium hillanum* in the Ariyalur beds is not inconsistent with the facts known about its distribution.

From these considerations it is quite clear that no Trichinopoly bed is present at Shillagoody. The

(9). 'Von grosser stratigraphischer Wichtigkeit sind in dieser Fauna *Schlænbachia Dravidica* Kossm and *Placenticeras tamulicum*, (Blanf) Kossmat, denn beide sind mit sehr bezeichnend Leitformen des untersenonen nahe verwandt, ja sogar specifisch nur schwer von den ausländischen Repräsentaten der gleichen Formengruppe trennbar.' (Kossmat—op. cit. pp 198-199).

(10). Pal. Ind., Ser. VI, Vol. III, p. 220. Doubts have, however, been expressed regarding the identification of this species as will appear from the following:—

Specimens from the Trichinopoli group of Southern India were identified with *Protocardium hillanum* by Forbes and Stoliczka, who stated that they were unable to draw any line of separation between the Indian and European examples. The concentric ribbing is coarser in most of the Indian forms, and in some the smooth inner portions of the posterior area, is relatively larger than in specimens from Blackdown (Woods. Monogr. Pal. Soc. LXII, 1908, p. 200).

palæontological evidences, on the other hand, all point to the conclusion that, as shown in Blanford's map, the area belongs to the Ariyalur group. Thus we have to arrive at the second alternative of assigning a wider range to *Placenticeras tamulicum* Kossmat *i.e.*, from the lower senonian to campanian It may be pointed out here that this is the only species of *Placenticcras* that is found throughout the whole of the senonian, the other senonian species of the genus being confined either to the lower or to the upper division.

PROCEEDINGS

OF THE

INDIAN ASSOCIATION FOR THE CULTIVATION OF SCIENCE.

Vol. II. No. 3.

Saturday, the 23rd September, 1916, at 5 P.M.
C. V. Raman, Esq., M.A., Vice-President, in the chair.

On Discontinuous Wave-Motion.

Part II.

By

C. V. RAMAN, M.A., and ASHUTOSH DEY.

In an important paper on the theory of discontinuous wave propagation,* Harnack has given an elegant general formula expressing the mode of vibration of a string, whose configuration is completely determined by a finite number of discontinuous changes of velocity travelling over it. As an illustration of his result, Harnack has discussed in detail the cases, in which the form of vibration is determined by one, and by two such changes of velocity respectively. The analysis indicates that the case of a single discontinuity is identical with that of the principal mode of vibration of a bowed string, and in a previous communication

* A Harnack, *Mathematische Annalen*, Vol. 29, Page 486.

from this laboratory,† it has been shown how this mathematical result may be confirmed experimentally. The general case of two discontinuities considered by Harnack covers a considerable and interesting variety of forms of vibration, and the method described in the previous paper has now been successfully extended so as to obtain an experimental confirmation of Harnack's results in some of these cases also.

Experimental Method.

If C_1 and C_2 represent two discontinuous changes of velocity travelling on a string of finite length which completely determine its motion, the velocity-diagram of the string must in general consist of three parallel straight lines as shown in Fig. 1(*a*) or Fig. 1(*b*). Each of the two outer lines passes through one of the fixed ends of the string and is separated from the intermediate line by a discontinuity.

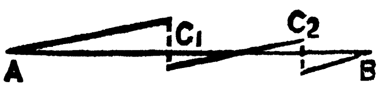


Fig. 1(*a*).

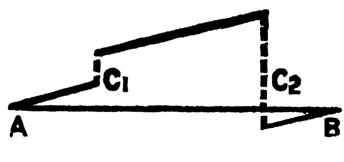


Fig. 1(*b*).

In Fig. 1 (*a*), the discontinuities are of the same sign, and in Fig. 1(*b*), they are of opposite signs. A velocity-distribution similar to that shown in either of the figures would be obtained if a string has initially a uniform angular velocity about a point in its own line, and if in the course of this motion, the two points A and B, are suddenly fixed, either simultaneously or

† C. V. Raman, M. A. and S. Appaswamaiyar, 'on Discontinuous Wave-Motion.' Phil. Mag., Jan., 1916.

else successively at an interval less than that necessary for an impulse to travel from A to B or *vice-versa*. If the point about which the string has initially a uniform angular velocity, lies within A B, we have the case shown in Fig. 1(*a*). If it lies in B A produced, the velocity-distribution is similar to that shown in Fig. 1(*b*). The photographic records presented with this paper (Plate I) refer to a case in which the string has initially a uniform angular velocity about a point lying outside the two fixed stops A and B; and the discontinuous changes of velocity, which determine the form of vibration, are therefore of opposite signs.

The method by which the records are obtained is similar to that described in the previous paper, but with certain necessary modifications. The tension and initial motion of the string are, as before, secured by a weight attached to its free end which is allowed to swing down in the manner of a Pendulum. The stops A and B are placed approximately in a vertical line below the point of suspension of the string. As soon as the string impinges on the lower stop B, the weight swings inwards, and the end B is thus effectually fixed. The upper stop A, however, presents some difficulty as it is practically in the same line as that joining B with the point of suspension, and does not therefore, except at the first impact, effectually fix the string at A. To avoid this difficulty, a small cylinder of soft iron is fixed to the string midway between A and its point of suspension, and an electro-magnet is provided which when the string reaches the vertical position carrying the cylinder with it, draws

the latter inwards and then holds it. The stop at A is thus rendered completely effective. The initial motion at any point on the string between A and B and its subsequent vibration are photographically recorded on sensitive paper contained in a dark slide which moves downwards behind an illuminated slit set across the string.*

When the position of the stops A and B is such that the string impinges upon both simultaneously, the impulses cross one another midway between A and B, and the resultant vibration is then necessarily symmetrical. The first six records shown in the plate refer to the motion at different points when this condition is practically attained. The last record however shows a different case in which the string is fixed at the stop A an appreciable interval after it is fixed at B. The condition is attained by drawing A, a little out of the straight line joining B and the point of suspension. The discontinuities cross elsewhere than at the centre of the string twice in each period of vibration, and the vibration curves are then necessarily asymmetrical. This is evident from the record shown.

Theory.

The theoretical form of the vibration curves at any specified point may be deduced from the velocity-diagram. For, the velocity at any given point on the string is unaffected by the motion of the discontinuities except when one of them actually passes over it.

* For facility of work, it is arranged that the weight and string are released electromagnetically. Simultaneously an auxiliary pendulum is released which after an adjustable interval of time breaks a contact and releases the photographic slide.

Successive velocities and the intervals for which they subsist are thus known, and the vibration-curve which represents the resulting displacements may be plotted from these values without difficulty. The records shown in the plate are found to be completely in agreement with the results thus obtained. The special feature of interest is that the vibration-curves are seen to be intermediate in form between the two-step zig-zags of a bowed string and those characteristic of a plucked string* The reason for this is not far to seek. When one of the discontinuities is zero, we have, as already seen, the case of the bowed strings.

When $C_1 = -C_2$, the motion reduces exactly to that of a string plucked at the point at which the discontinuities cross. The cases actually recorded in these experiments are those in which C_1 and C_2 are unequal but of opposite signs and are thus intermediate between the two extreme types referred to above.

The cases in which C_1 and C_2 are of the same sign are also of interest in connection with the theory of the special forms of vibration of a bowed string obtained at the "wolf-note" Pitch, and also under other conditions when the vibration-curves assume the form of four-step zig-zags. Experiments are being undertaken to reproduce these special forms of vibration by the method indicated in this paper.

Summary and Conclusion.

In these experiments, the characteristic vibration-forms produced by the motion of two unequal discon-

* Krigar-Menzel and Raps, *Sitzungberichte* of the Berlin Academy, 1893, Page 509.

tinuous changes of velocity of opposite signs have been observed and recorded photographically. Some are of the symmetrical type and the others are asymmetrical. The results are in full agreement with the mathemetical theory first given by Harnack. The vibration curves are found to be intermediate in form between those charactaristic of bowed and of plucked strings. The cases in which the discontinuities are of the same sign are also of special acoustical interest and will be studied separately.

On the Method of distinguishing between Calcite and Aragonite by staining by Aniline Black.

By Sures Chandra Datta, M.Sc.

Cobalt nitrate is generally employed to distinguish between calcite and aragonite while iron sulphate, silver nitrate, kongoroth and alizarin may also be used for the purpose [1]; but the effect of aniline black (benzo azurin) as a stain on calcite and aragonite with a view to distinguish between them has not been studied as yet [2]. The application of this stain for the purpose of distinguishing between calcite and aragonite is very simple and the details of an experiment are given below :—

Powdered calcite and aragonite are taken in two separate test tubes; very dilute sulphuric acid is poured into each and boiled; then solution of aniline black is added and minerals are boiled in the solution of sulphuric acid and aniline black for sometime; liquid is drained off and the minerals are washed several times in cold boiling water when the powders of calcite and aragonite are observed to have violet and blue stains on them respectively. Sulphuric acid may, however, be replaced by many other acids and salts but still a difference in the nature of the stain will be observed and the purpose of this short note is to put on record these observations. It may be observed, however, that the intensity of colour assumed by calcite is not the same in all cases, in some cases the colour is very deep, in others lighter. This remark is

(1) Dœlter's works.

(2) *Ibid.*

applicable also to the case of aragonite. In some cases after washing with boiling water, two or three times, the stain, assumed by calcite powder, is deeper than that of aragonite, in other cases it is the reverse. When the minerals are boiled only in solution of aniline black in water there is also a stain on the minerals and the intensity of this stain varies with the treatment with acids and salts as stated before. Following is a complete list of experiments—the experiments being conducted on the method outlined above.

The solution of acid or salt in which calcite and aragonite powders are separately boiled before the addition of aniline black solution in water.	Stain on calcite.	Stain on aragonite.	REMARK.
The minerals boiled in the solution of aniline black in water only.	Violet ...	Blue ...	α ; x
Sulphuric acid ...	Light violet ...	Do. ...	α ; x
Nitric acid ...	Ditto ...	Do. ...	α ; x
Hydrochloric acid ...	Very light violet	Do. ...	α ; x
Phosphoric acid ...	Practically white *i.e.*, *nil.*	Bluish tinge ...	α ; x
Oxalic acid ...	Deep violet ...	Deep blue ...	α ; x
Tartaric acic ...	Light violet ...	Do. ...	α ; x
Citric acid ...	Do. ...	*Nil*	α ; y
Acetic acid ...	Do. ...	Blue ...	α ; x
Formic Acid ...	*Nil* (nearly) ...	Do. ...	α ; x
Lactic acid ...	Light shade of violet.	Light blue ...	α ; x

The solution of acid or salt in which calcite and aragonite powders are separately boiled before the addition of aniline black solution in water.	Stain on calcite.	Stain on aragonite.	REMARK.
Picric acid ...	Light violet ...	Blue ..	α ; x
Succinic acid ...	Light violet (on washing once with cold water.)	Practically white *i.e.*, *nil* (on washing once with cold water.)	β ; y
Salicylic acid ...	Violet ...	Blue ...	r ; x
Malic acid ...	Light violet ...	*Nil* (nearly) ...	β ; y
Malonic acid ...	Do. ...	*Nil* (nearly) ...	β ; y
Meconic acid ...	Violet ...	Bluish ...	α ; y
Phtalic acid ...	Light violet ...	Blue ...	α ; x
Uric acid ...	Dull violet ...	Rich blue ...	α ; y
Gallic acid ...	Very light shade of violet nearly white (on washing once with cold water.)	Shade of Blue (on washing once with cold water).	α ; x
Benzoic acid ...	Violet ...	Blue ...	α ; x
Ammon-sulphate ...	*Nil*	Do. ..	α ; x
Ammon-chloride ...	Light shade of violet.	Light shade of blue.	r ; y
Ammon-nitrate ...	Light violet ...	Blue ...	α ; x
Ammon oxalate ...	Rich violet ...	Do. ...	α ; y
Ammon tartrate ...	Light violet ...	Light shade of blue.	β : y
Ammon citrate ...	Light shade of violet (on washing once with cold water.)	*Nil* (on washing once with cold water).	r ; y
Ammon acetate ...	*Nil*	Blue ...	α ; x
Ammon benzoate ...	Light violet ...	Do. ...	α ; x
Ammon phosphate ...	Violet ...	Do. ...	α ; x

α—Very easily distinguishable after 2nd or 3rd washing.

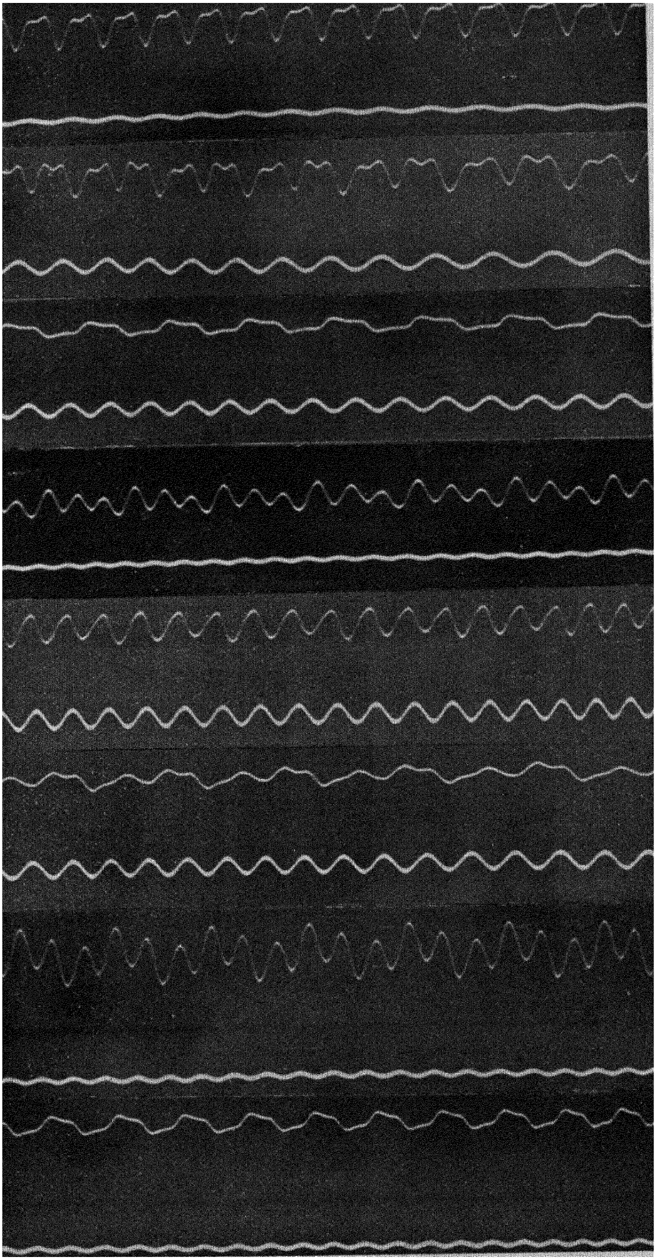
β—Easily distinguishable after 2nd or 3rd washing.

γ—Distinguishable with difficulty.

x—Colour on aragonite is deeper than that on calcite.

y—Colour on calcite is deeper than that on aragonite.

N.B. The stains on the powders of calcite and aragonite fixed by the method outlined above, are better distinguished under water than when they are dry. The intensity of stain on either of the minerals, calcite and aragonite, is not the same always, same acid or salt being used. But under the same conditions, with the same acid or salt there is always a difference between the stains on the minerals calcite and aragonite—the stained minerals being washed first in cold water when the intensity remains great though also there is great difference between the stains on calcite and aragonite, but this intensity decreases somewhat in some cases, but in others colour practically disappears on washing with boiling water afterwards.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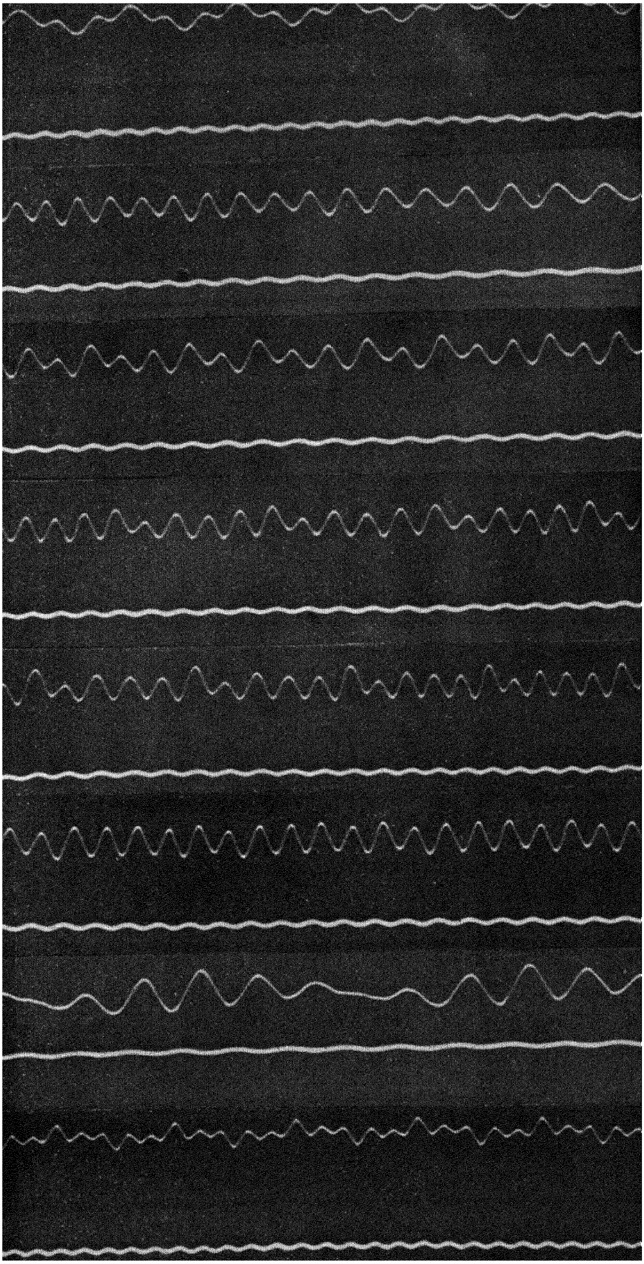

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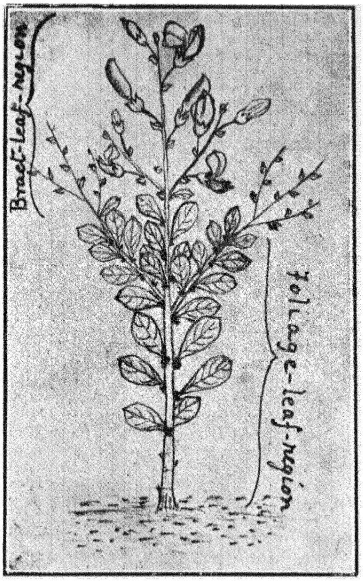


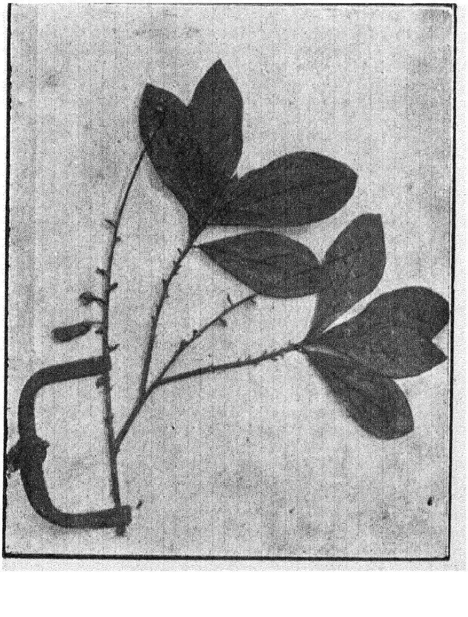


Fig. 2.

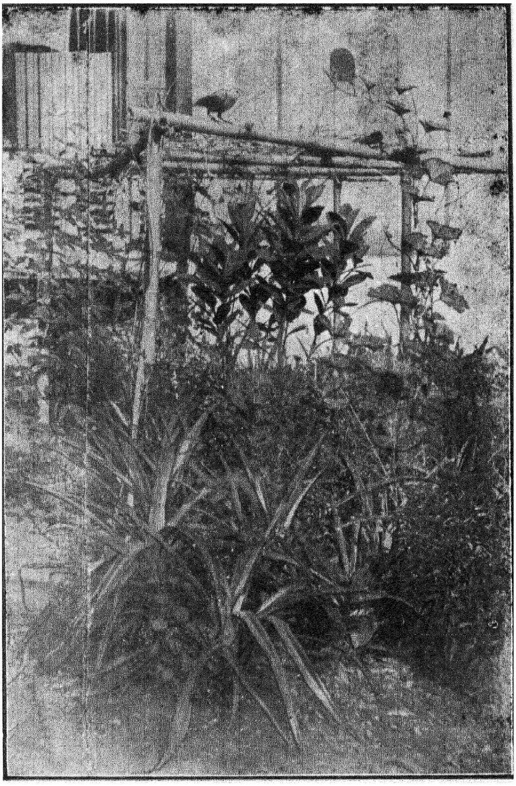


Fig. 3.


Inflorescence
Vegetative Bud

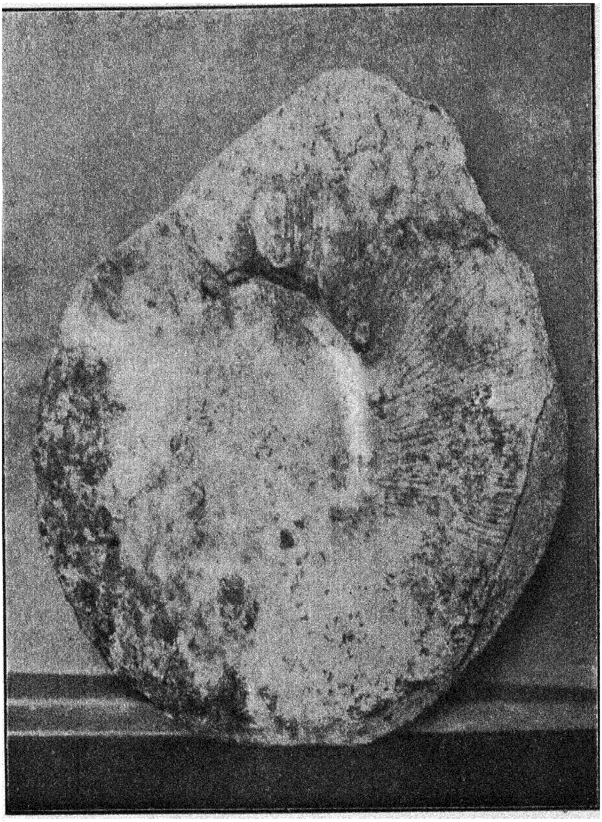
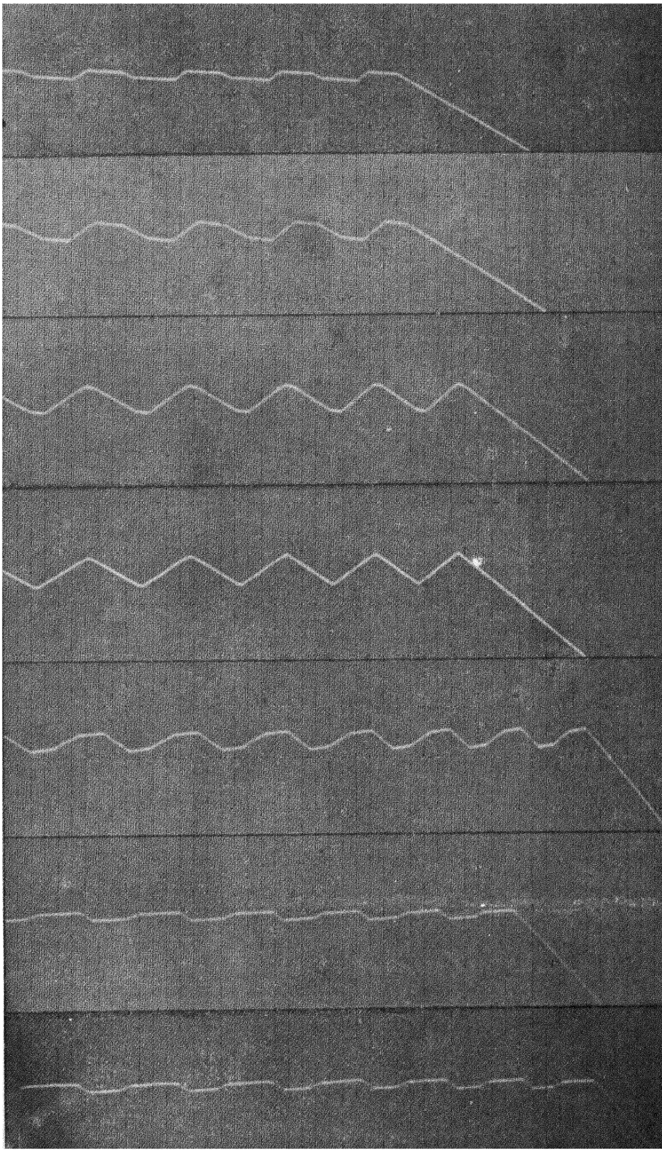


Photo by B. Maitra.

Placenticeras tamulicum Kossmat

Observed at



l 9

l 4

2l 5

l 2

3l 4

8l/9

1l/9

Photographs of vibration-curves showing the initial motion and the subsequent vibration with discontinuous changes of velocity.